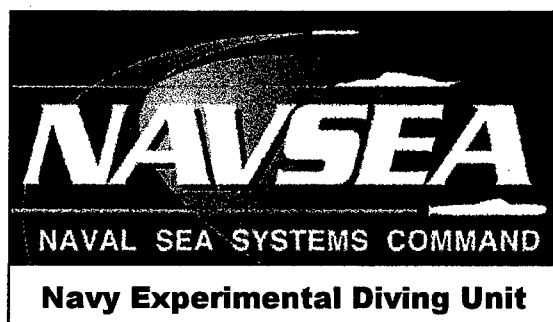


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**EVALUATION OF THE KMS 48
REPLACEMENT FULL FACE MASK
WITH THE EMERGENCY
BREATHING SYSTEM
FOR USE WITH MK 16 MOD 1
UNDERWATER BREATHING
APPARATUS**

20060213 046

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INTRODUCTION

Navy Experimental Diving Unit (NEDU) was tasked by references (1) and (2) to test and evaluate the MK 16 MOD 1 underwater breathing apparatus (UBA) for use as an emergency breathing system (EBS) in conjunction with the KMS 48 full face mask (FFM). Testing was designed to assess the abilities of the KMS 48 FFM and the MK 16 MOD 1 to perform as an EBS during unmanned and manned open water dives to the maximum operational working depths for each breathing medium: 190 feet of seawater (fsw) [58.2 meters of seawater (msw)] with nitrox (N_2O_2), and 300 fsw (91.9 msw) with heliox (HeO_2).

Primarily employed by Naval Explosive Ordnance Disposal (EOD) divers, the MK 16 MOD 1 UBA is an electronically controlled, closed-circuit, mixed-gas, constant oxygen partial pressure (PPO_2), underwater life-support system that meets military specifications for nonmagnetic and acoustically safe equipment. Its use allows the mobility of a free-swimming diver to be combined with the depth advantages of mixed gas. In the EBS configuration (Figure 1) the MK 16 MOD 1 UBA will be mounted on the EBS frame and charged with the same diluent gas as for the planned dive. The EBS will be deployed for all planned decompression dives.

The KMS 48 FFM (Figures (2) and (3)) was selected to replace the MK 24 and the Cressi-sub FFMs. The design of the KMS 48 allows a diver to change breathing sources without having to remove the face mask underwater. Overall, this design will improve diver safety by mitigating the disorientation caused by cold water during mask removal when shifting to the EBS. The reduced size and weight of the KMS 48 offers improved swimming performance and diver comfort than that of the bulky MK 24. The KMS 48 also is fully compatible with the selected communication system.

The purposes of the study were to assess the MK 16 MOD 1 UBA as an EBS and to evaluate how effectively the KMS 48 FFM could be combined with the proposed MK 16 EBS in ways that maintain the EBS's communication connections. Tests were conducted at the maximum working depths of the UBA.

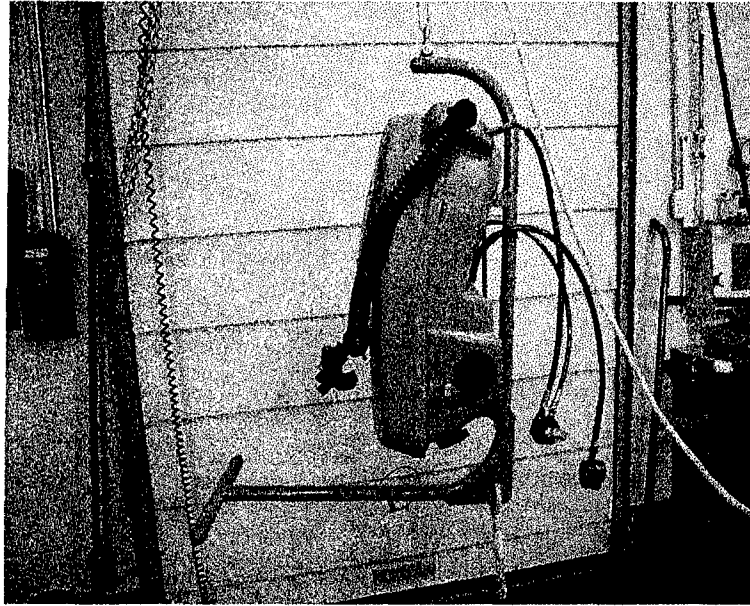


Figure 1. Emergency Breathing System with frame



Figure 2. KMS 48 Full Face Mask

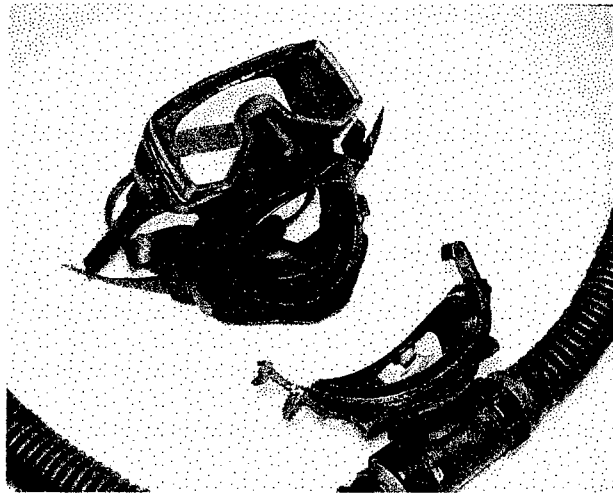


Figure 3. KMS 48 FFM with Pod Detached

METHODS

UNMANNED EVALUATION

GENERAL

KMS 48 testing involved unmanned tests in the Experimental Diving Facility (EDF) to ensure that breathing resistance and carbon dioxide (CO_2) washout (ventilatory sufficiency) were within acceptable limits. The following personnel and logistical support were required for testing: four KMS 48 FFMs, two MK 16 MOD 1 UBAs, and the EDF manned with a complete watch section.

Unmanned testing of the MK 16 MOD 1 as an EBS was performed in the Experimental Diving Facility (EDF) to ensure that the UBA maintained an acceptable level of PPO_2 without the oxygen metabolism of the diver.

Part of this evaluation included a comparison between the resistive effort of the KMS 48 attached to a MK 16 MOD 1, and the historical EDF data on the MK 16 MOD 0 with a mouthpiece (T-bit).

EXPERIMENTAL DESIGN AND ANALYSIS

KMS 48

The objective of this test was to evaluate the KMS 48 FFM's influence on MK 16 MOD 1 breathing resistive effort and CO_2 washout, to a maximum excursion depth of 300 fsw. All unmanned testing was conducted per reference (3), with the following exceptions:

- (1) Comparison of established breathing resistances for the MK 16 MOD 0 fitted with the MK 24 FFM per reference (4) and those for the MK 16 MOD 1 fitted with the KMS 48 FFM. Water temperatures during testing were 29 and 104 °F.
- (2) Representation of inspired CO₂ at each depth — 33, 99, and 190 fsw (10.1, 30.3, and 58.2 msw) with N₂O₂, and 130, 198, and 300 fsw (39.8, 60.7, and 91.9 msw) with HeO₂.
- (3) Each KMS 48 mask was tested at five separate RMV rates and with two MK 16 diluents: 79/21 N₂O₂ to a maximum depth of 190 fsw, and 88/12 HeO₂ to a maximum depth of 300 fsw.

MK 16 MOD 1 (EBS)

Testing the MK 16 MOD 1 as an EBS consisted of a series of unmanned tests in the EDF. The objective was to verify the PPO₂ in the MK 16 MOD 1 via the EDF MK 16 data acquisition box (EMDAB) in fresh water to a depth of 150 fsw (45.9 msw), 190 fsw (58.2 msw), and 300 fsw (91.9 msw). Requested deliverables were documented logs of all MK 16 MOD 1 PPO₂ readings from sensors 1, 2, and 3 at each depth. Sensor readings are documented in Table 3.

EQUIPMENT AND INSTRUMENTATION

KMS 48

Evaluation of four KMS 48 FFMs was conducted in the EDF. Because of differences in test depths, each mask was tested with two different diluent mixes and at two different temperatures. In increments of 33 fsw, or one atmosphere absolute (ATA), the EDF was pressurized to the maximum depth of 300 fsw. At each ATA, breathing resistance data were collected. (BPM = breaths per minute; RMV = respiratory minute volume; SLPM = standard liters per minute; STPD = standard temperature pressure dry)

- a. Temperatures: cold water: 29±2.0 °F (-1.7±1.1 °C)
warm water: 104±2.0 °F (40±1.1 °C)
- b. Diluent gases: 79/21 N₂O₂ at 0–190 fsw (0–58.2 msw)
88/12 HeO₂ at 130–300 fsw (39.8–91.9 msw)
- c. Breathing Rate / Tidal Volume / RMV

| | | | | |
|--------|---|------------|---|--------------------|
| 15 BPM | / | 1.5 liters | / | 22.5 liters/minute |
| 20 BPM | / | 2.0 liters | / | 40.0 liters/minute |
| 25 BPM | / | 2.5 liters | / | 62.5 liters/minute |
| 30 BPM | / | 2.5 liters | / | 75.0 liters/minute |
| 30 BPM | / | 3.0 liters | / | 90.0 liters/minute |

| | |
|----------------------|--------------------------------|
| d. RMV liters/minute | CO ₂ Injection Rate |
| 22.5 | 0.90 SLPM at STPD |
| 40.0 | 1.35 SLPM at STPD |
| 62.5 | 2.50 SLPM at STPD |
| 75.0 | 3.00 SLPM at STPD |
| 90.0 | 3.60 SLPM at STPD |

Equipment and instrumentation in the EDF Bravo Chamber — with its insulated rectangular water container (ark) having a 550-gallon capacity and a capability for setting and maintaining water temperatures ranging from 29 °F (−1.7 °C) to 104 °F (40 °C) — included the following:

- a. Test stand with 90th percentile rubber head simulator (mannequin) mounted in a vertical position
- b. Mechanical breathing simulator, Reimers Dual piston, variable volume 1–6 liters (L) and frequency to 60 cycles per minute; calibrated volume stops at 1.5, 2.0, 2.5, and 3.0 L; calibrated frequency stops at 15, 20, 25, and 30 BPM sinusoidal waveform
- c. AMETEK CD3A fast-response CO₂ analyzer
- d. PC Pentium 200 megahertz (MHZ) NT Workstation computer system, with National Instruments Lab VIEW data acquisition software and NEDU-developed software for processing resistive effort data
- e. Oral/nasal differential pressure transducer (Keller, Inc., model 289–545–0001), ±1 pounds per square inch differential (6.9 kilopascals [kPa])
- f. Matheson mass flow controller (model 8280), to inject CO₂ at 0–3.6 SLPM at STPD
- g. Two Genie model 102 membrane separators for separating water from gas samples
- h. Two MK 16 MOD 1 UBAs
- i. Four KMS 48 FFM

MK 16 MOD 1 (EBS)

- a. Three MK 16 MOD 1s
- b. Diluent gas: 88/12 HeO₂ at 150-300 fsw (45.9-91.9 msw)
79/21 N₂O₂ at 190 fsw (58.2 msw)
- c. Record water temperature.

- d. Data acquisition computer
- e. EDF MK 16 Data Acquisition Box
- f. Oxygen Sensor Calibration Chamber

PROCEDURES

KMS 48

- a. Conducted initial setup/pre-dive on UBA, per reference (5)
 - (1) Gas supply was provided via candidate UBA's installed gas cylinders.
 - (2) Only NAVSEA-authorized CO₂ absorbent (high performance Sodasorb) was used, per reference (6).
- b. Configured UBA/FFM
- c. Connected mannequin with UBA to chamber breathing machine
- d. Conducted dive profile per test parameters

MK 16 MOD 1 (EBS)

Evaluation of three MK 16 MOD 1s was conducted. The EDF was pressed to 150, 190, and 300 fsw.

- a. Obtained calibration curves for each O₂ sensor prior to MK 16 setup.
- b. Conducted the initial setup/pre-dive on the UBA in accordance with reference (5).
- c. Configured the UBA in chamber with the mouth piece barrel valve in the closed position.
- d. Connected primary and secondary display cables to EMDAB.
- e. Conducted the dive profile, three rigs per each test depth in accordance with test parameters:
 - 1) 150 fsw 88/12 HeO₂ diluent, travel rate=60 fpm and a left surface PPO₂ of .75±.05
 - 2) 300 fsw 88/12 HeO₂ diluent, travel rate=60 fpm and a left surface PPO₂ of .75±.05
 - 3) 190 fsw 79/21 N₂O₂ diluent, travel rate=60 fpm and a left surface PPO₂ of .75±.05

RESULTS

KMS 48

Comparisons were made of the resistive breathing effort (work of breathing) for a MK 16 MOD 1 with a KMS 48 mask and historical data for the MK 16 MOD 0 with a mouthpiece. The resistive effort for the MK 16 MOD 1 was measured with the UBA completely immersed in the upright position. Tests were done at 22.5, 40, 62.5, 75, and 90 L/min at depths of 0, 33, 66, 99, 132, and 165 fsw.

The water temperature for the MK 16 MOD 0 with the mouthpiece was 75 °F (24 °C). The MK 16 MOD 1 with the KMS 48 mask was tested at two temperatures (29 and 104 °F, -2 and 40 °C) and the results presented here are the average of the two temperatures. Results are presented in Tables (1) and (2). A statistical comparison (paired t-tests) between the two configurations showed that the resistive effort was, on the average 23.1% higher ($p < 0.0001$) for the MK 16 with the KMS 48 mask. The range was 9.1% to 44.3%.

Table 1. Resistive effort for the MK 16 with a mouthpiece

| Ventilation (L/min) | Depth (fsw) | | | | | |
|------------------------|-------------|------|------|------|------|------|
| | 0 | 33 | 66 | 99 | 132 | 165 |
| 22.5 | 0.22 | 0.27 | 0.33 | 0.37 | 0.39 | 0.43 |
| 40 | 0.37 | 0.48 | 0.61 | 0.73 | 0.83 | 0.95 |
| 62.5 | 0.59 | 0.91 | 1.21 | 1.43 | 1.7 | 1.98 |
| 75 | 0.80 | 1.3 | 1.66 | 1.99 | 2.41 | 2.72 |
| 90 | 1.09 | 1.78 | 2.31 | 2.79 | 3.35 | 3.83 |

Table 2. Resistive effort for the MK 16 with a KMS 48 mask

| Ventilation (L/min) | Depth (fsw) | | | | | |
|------------------------|-------------|------|------|------|------|------|
| | 0 | 33 | 66 | 99 | 132 | 165 |
| 22.5 | 0.32 | 0.38 | 0.43 | 0.47 | 0.51 | 0.56 |
| 40 | 0.48 | 0.66 | 0.78 | 0.91 | 1.04 | 1.18 |
| 62.5 | 0.76 | 1.15 | 1.48 | 1.78 | 2.09 | 2.42 |
| 75 | 0.94 | 1.47 | 1.94 | 2.36 | 2.79 | 3.27 |
| 90 | 1.19 | 1.95 | 2.59 | 3.18 | 3.79 | 4.34 |

MK 16 MOD 1 (EBS)

Three MK 16 MOD 1s were individually tested using a left surface condition of $.75 \pm .15$ PPO₂ using an 88/12 helium-oxygen (HeO₂) diluent to a depth of 150 fsw and 300 fsw. A diluent of 79/21 N₂O₂ was used for the 190 fsw test. All testing was done at the travel rate of 60 fpm. All PPO₂ values are reflected in Table (3).

Table 3. Average O₂ levels of three MK 16 MOD 1 UBAs recorded at various depths.

| | | | | Sensor readings | | | External analyzer | | | |
|-------------------------------|-------|--------|--------|-----------------|------|------|-------------------|------|------|---------|
| | max | Travel | sensor | Rig number | | | Rig number | | | labels |
| Diluent | depth | rate | R10-DV | 320 | 327 | 1027 | 320 | 327 | 1027 | |
| N ₂ O ₂ | 190 | Normal | R10-DV | 2.28 | 1.97 | 1.99 | 2.72 | 2.86 | 2.11 | sensors |
| HeO ₂ | 150 | Normal | R10-DV | 1.9 | 1.81 | 1.97 | 1.55 | 1.55 | 1.79 | hose |
| HeO ₂ | 300 | Normal | R10-DV | 2.28 | 2.36 | 2.17 | 2.02 | 1.9 | 2.67 | |
| HeO ₂ | 150 | slow | R10-DV | 1.57 | x | x | 1.37 | x | x | |
| HeO ₂ | 150 | Normal | R10-DN | 1.78 | x | x | 1.71 | x | x | |

The time that the O₂ add valve was open was on the average 56 seconds (range 40 to 73 s) for the R10-DV sensor. The faster R10-DN sensor was used in one additional dive to 150 fsw with HeO₂. During this dive, the O₂ add valve was opened five times for a total of 16 seconds.

CONCLUSIONS/RECOMMENDATIONS

KMS 48

The resistive effort for the MK 1 MOD 1 with KMS 48 mask was on the average 23.1% higher ($p < 0.0001$, by paired t-test) than the historical data for the MK 16 MOD 0 with T-bit mouthpiece.

MK 16 MOD 1 (EBS)

Estimate of a worst case of high PO₂

The partial pressure of O₂ that the diver would be exposed to after switching to the EBS can be surmised by estimating the volume of the MK 16, the diver's lung volume and the partial pressure of O₂ in each.

Volume of gas in the EBS. When the MK 16 EBS is lowered, the breathing bag collapses until the diluent add valve opens; the bag will stay close to this new volume until someone breathes on it. The stated breathing loop volume in the MK 16 is 8.5 L.

We don't know precisely how much gas is in the UBA when the diluent add valve quits firing, but as shown below we can estimate the effect of having UBA volumes ranging from 3.5 L to 5.5 liters when at the bottom. We do know from Table (3) that in tests of three UBAs at 300 fsw, the average PPO₂ in the UBA was 2.27 ATA, and at 150 fsw, the average PPO₂ was about 1.9 ATA.

Diver gas volume. When an average sized, 50th percentile diver starts breathing on the EBS, he may have a fairly small total gas volume (functional residual capacity) of, say, 3.9 L.

Resulting O₂ level. The PPO₂ which results when gas from the diver mixes with gas from the UBA can be found from the following mixing equation:

$$PPO_{2mix} = \frac{((V_{EBS} \cdot PPO_{2EBS}) + (V_{diver} \cdot PPO_{2diver}))}{V_{EBS} + V_{diver}}$$

where V_{EBS} is the gas volume of the EBS on the bottom, V_{diver} is the gas in the diver's lungs when he switches to the EBS, and PPO₂ is given for both the EBS and the diver when he switches over.

Table 4. PPO₂ after mixing of diver and EBS gas at 300 fsw.

| V _{EBS} (L) | PPO _{2 EBS} (ATA) | V _{diver} (L) | PPO _{2 diver} (ATA) | PPO _{2 mix} (ATA) |
|----------------------|----------------------------|------------------------|------------------------------|----------------------------|
| 3.5 | 2.30 | 3.9 | 1.30 | 1.77 |
| 4 | 2.30 | 3.9 | 1.30 | 1.81 |
| 5 | 2.30 | 3.9 | 1.30 | 1.86 |
| 5.5 | 2.30 | 3.9 | 1.30 | 1.89 |
| 5.5 | 2.30 | 5 | 1.30 | 1.82 |

If a diver were to switch over to the EBS at 300 fsw, the mixed PPO₂ would remain below 1.9 ATA for any reasonable gas volumes in the UBA.

Table 5. PPO₂ after mixing of diver and EBS gas at 150 fsw.

| V _{EBS} (L) | PPO _{2 EBS} (ATA) | V _{diver} (L) | PPO _{2 diver} (ATA) | PPO _{2 mix} (ATA) |
|----------------------|----------------------------|------------------------|------------------------------|----------------------------|
| 3.5 | 1.90 | 3.9 | 1.30 | 1.58 |
| 4 | 1.90 | 3.9 | 1.30 | 1.60 |
| 5 | 1.90 | 3.9 | 1.30 | 1.64 |
| 5.5 | 1.90 | 3.9 | 1.30 | 1.65 |
| 5.5 | 1.90 | 5 | 1.30 | 1.61 |

When used at a more conventional depth for a 300 fsw dive, (10 fsw below the first decompression stop), then mixed PPO₂ remains below 1.7 ATA.

METHODS

MANNED EVALUATION

GENERAL

The testing of the KMS 48 FFM and MK 16 MOD 1 as an EBS was conducted in three phases. Phase I of the KMS 48 test involved manned form, fit and function (FFF) testing in the test pool. Phase II involved manned diving in the OSF in conjunction with EBS testing. Phase III involved manned open-water depths to 300 fsw/certification dives for the MK 16 MOD 1 utilizing the KMS 48 FFM and the MK 16 MOD 1 EBS.

The following personnel and logistical support were required:

Phase I: two KMS 48 FFMs with PDAs, two modified MK 7 communications systems, four MK 16 MOD 1 UBAs and a manned dive station on the test pool and the Naval Diving and Salvage Training Center's (NDSTC) 50 Foot Buddy Breathing Ascent Training (BBAT) tower with a minimum of ten divers, and a minimum of five divers during BBAT tower dives.

Phase II: two KMS 48 FFM with PDAs, two modified MK 7 communications systems, four MK 16 MOD 1 UBAs and the OSF manned for diving and four divers.

Phase III: three KMS 48 FFM with PDAs, two modified MK 7 communications systems, four MK 16 MOD 1s, one dive boat outfitted with dive station load-out for open-ocean diving for two divers. For all manned dives, a qualified MK 16 diving supervisor was present.

EXPERIMENTAL DESIGN AND ANALYSIS

KMS 48

The objective of this test was to evaluate the form fit and function of KMS 48 FFM when diving to the maximum operational limits of MK 16 MOD 1.

MK 16 MOD 1 (EBS)

Testing the MK 16 MOD 1 as an EBS consisted of a series of manned tests conducted in the three phases. Phase I of the EBS test involved manned diving, executing the switch-over procedure in the test pool. Phase II involved manned diving in the OSF in conjunction with KMS 48 testing. Phase III involved manned open water testing to depths of 300 fsw utilizing the KMS 48 FFM. The certification dives for all components were conducted in this phase.

EQUIPMENT AND INSTRUMENTATION

The following equipment was used during testing:

- a. two KMS 48 FFMs with PDAs
- b. four MK 16 MOD 1 UBAs with HeO₂ (88/12) for 300 fsw and N₂O₂ (79/21) 190 fsw (no "D" dive)
- c. MK 23 Oxygen Transfer Pump Apparatus (OTPA) / high-pressure charging station
- d. EBS and EBS frame
- e. Modified MK 7 (Ocean Technology Systems) communications system
- f. 7.3-meter Rigid Hull Inflatable Boat, with complete dive station load-out

PROCEDURES

Manned evaluation of the KMS 48 FFM in conjunction with the MK 16 MOD 1 and EBS systems was conducted by divers using safe diving practices, as set forth in references (5) and (6).

Phase I Testing - This phase was conducted in accordance with reference (7), Annex B, and consists of the following:

Day 1: Form, fit, and function in NEDU Test Pool to familiarize the diver with the KMS 48 and the EBS.

Day 2: This testing was conducted at NDSTC's BBAT tower, and was a repeat of day one testing.

Phase II Testing - These dives were conducted in the NEDU OSF using the MK 16 MOD 1 UBA as the primary apparatus outfitted with the KMS 48 FFM, the new R10-DN O₂ sensors and the EBS and conducted in accordance with reference (7) Annex C.

Phase III Testing - The diving associated with this phase was conducted in open-water / open-ocean. A series of workup dives were conducted over a four-day period prior to the maximum operational testing. All diving in this phase was conducted in accordance with reference (7), Annex D.

RESULTS

PHASE I & II

KMS 48

The divers completed a series of dives consisting of pool and open water dives to evaluate the KMS 48 FFM. Dives were conducted at depths ranging from 15 fsw (4.6 msw) to 300 fsw. Divers completed a human factors questionnaire containing 22 questions after each dive. A set of statistics describing the responses was compiled. The KMS 48 FFM was scored on a scale of 1 – 6, with 4.0 or above being an acceptable score (1 = poor, 4 = adequate, 6 = excellent). The resulting average of the human factors questionnaire is presented in Table (4). The questionnaire is located in Appendix A.

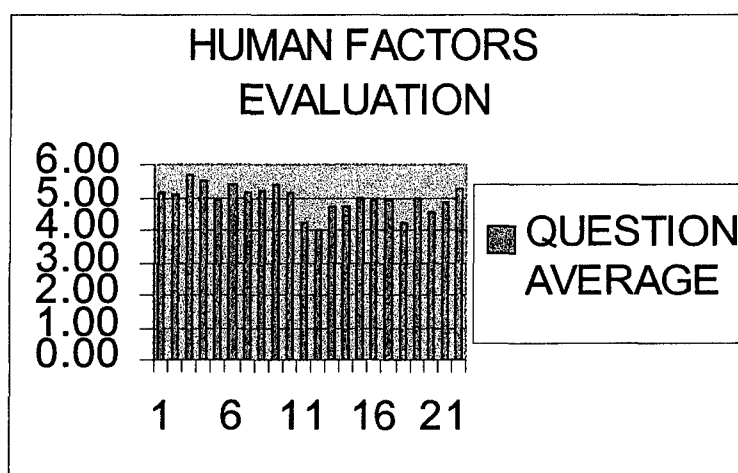


Figure 4. The average of each of the 22 questions in the Human Factors Questionnaires rating the KMS 48 FFMs.

MK 16 MOD 1 (EBS)

The test was conducted in accordance with reference (7) using four MK 16 MOD 1 UBAs utilizing Teledyne R-10DN O₂ sensors with two MK 11 BCDs and the KMS 48 FFM. The maximum oxygen partial pressure (PPO₂) observed during the 190 fsw and 300 fsw dives was over 1.99 ATA. The EBS secondary display only displays PPO₂ readings less than 2.0, so we were not able to determine the actual peak PPO₂ level. However, the "off-scale" PPO₂ levels were present for less than 2 minutes in all cases, and all PPO₂ were under 1.5 ata PPO₂ within four minutes after the divers began breathing on the EBS. One sensor failed high during a test dive; however, as expected that single failure had no effect on UBA O₂ control. The average PPO₂ for that dive was 1.3 ata at four minutes, and was 0.95 ata at six minutes.

Figure (5) shows the PPO_2 as a function of depth and on-gas time for the 190-fsw dives, while those for the 300-fsw dives are shown in Figure (6). The off-scale readings are clipped at 2.0 ata in the plots since we don't know the actual peak values.

Readings at zero minutes were taken at depth, but before the divers began using the EBS. Values plotted at one minute were recorded approximately one minute after the divers switched to the EBS; values plotted at two minutes were recorded two minutes after switchover to the EBS, etc.

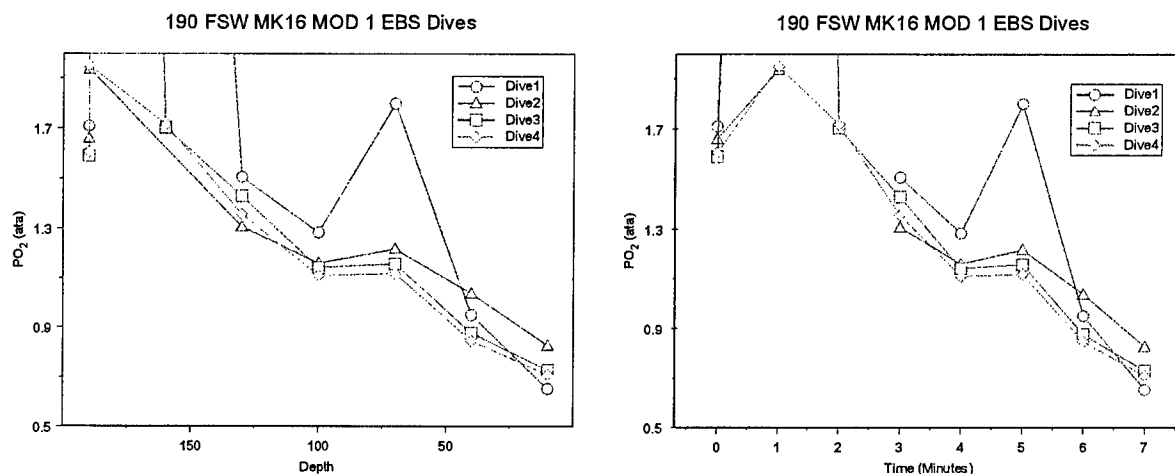


Figure 5. Average PPO_2 versus depth in fsw and time for the 190 fsw dives.

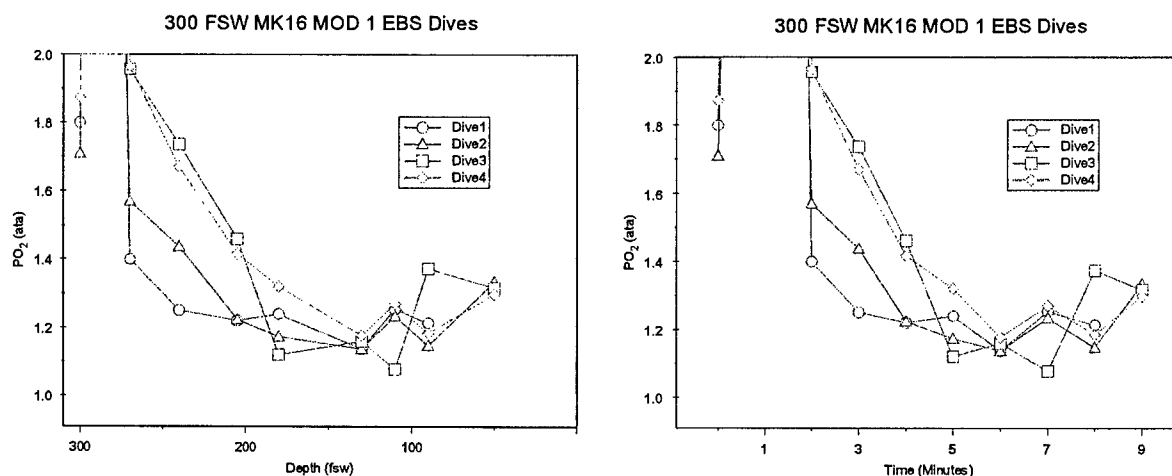


Figure 6. Average PPO_2 versus depth in fsw and time for the 300 fsw dives.

PHASE III

The 190 fsw N_2O_2 and 300 fsw HeO_2 certification dives were conducted in accordance with reference (7). Certification dives were uneventful and all equipment performed adequately.

CONCLUSIONS

KMS 48

The human factors evaluation and the performance of the KMS 48 FFM during the certification dives provided the necessary quantitative and qualitative data for acceptance of this equipment for use with the MK 16 MOD 1 UBA. The ability of the FFM to utilize the prospective EBS communication system was instrumental in the safe completion of the certification dives.

MK 16 MOD 1 (EBS)

The off-scale peak PPO_2 most likely occurred due to the mixing of the gas once the diver began breathing on the UBA (oxygen is injected on the inhalation side of the UBA, but would not be well mixed initially). The peak would be expected to drop as the gas became well mixed. However, the divers began their ascent soon after switchover to the EBS, so Boyle's Law expansion of the gas in the UBA would also cause a decrease of the PPO_2 . It is reasonable to expect that the PPO_2 would be high if the diver had remained at depth and not working, but it is also reasonable to expect that the diver would want to minimize time at depth during the emergency situation, so this potential risk is acceptable.

RECOMMENDATIONS

NEDU letter Ser 033/166 17 July 02 reported the completion of open-ocean testing of the Emergency Breathing System (EBS) and included a recommendation for the KMS 48 to be added to NAVSEA00CINST 10560 authorizing it for Navy use. NEDU letter Ser 033/267 29 Oct 02 reported the completion of the certification dives of the MK 16 MOD 1 and recommended the EBS for fleet usage.

REFERENCES

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2. Commander, Naval Sea Systems Command, Task Assignment 01-20, *Test and Evaluate the Underwater Breathing Apparatus (UBA) MK 16 MOD 1 for use as an Emergency Breathing System (EBS) for Program Executive Office, Mine and Undersea Warfare (PMS-EOD)*, 18 Sept 01.
3. Navy Experimental Diving Unit, *Unmanned Test Methods and Performance Goals for UBA*, NEDU Technical Manual No. 01-94, June 94.
4. K. Jones and L. Crepeau, *EX 24 Full Face Mask*, NEDU TR 5-93, Navy Experimental Diving Unit, May 1993.
5. U. S. Naval Sea Systems Command, *MK 16 MOD 1 Operation Manual*, NAVSEA 0910-LP-002, January 2002.
6. U. S. Naval Sea Systems Command, *U.S. Navy Diving Manual, Revision 4*; NAVSEA SS521-AG-PRO-10, Chapter 17, March 2002.
7. S. Stanek and C. Hedricks, *Manned Evaluation of the KMS 48 Replacement Full Face Mask (FFM) and the Emergency Breathing Apparatus (EBS) for use with the MK 16 MOD 1 Underwater Breathing Apparatus*, NEDU Protocol 02-06/32111 Change 2, Navy Experimental Diving Unit, 13 Sept 02.

APPENDIX A

HUMAN FACTORS EVALUATION QUESTIONNAIRE KMS 48 FULL FACE MASK

Name of Diver: _____ Date of Dive: _____
Actual Depth: _____ Actual Bottom Time: _____
Brief description of dive: _____

Diver's dress: _____

The following is the rating system to be used on the questionnaire:

| | | |
|------------------|--------|----------------------|
| 1 extremely poor | 2 poor | 3 not quite adequate |
| 4 adequate | 5 good | 6 excellent |

Over all comfort of the mask

1. How would you rate the ease of donning and doffing the mask? _____
2. How would you rate the ease of getting the harness over your head with the mask in place? _____
3. How would you rate the ease of tightening the straps? _____
4. How would you rate the ease of loosening the straps and doffing the mask? _____
5. How would you rate the visibility provided by the mask? _____
6. How would you rate the overall comfort of the mask as it fit your face? _____
7. How would you rate the ease of preventing gas leaks around the face seal? _____
8. How would you rate the balance of the mask? _____

Use and operation of the mask

9. How would you rate the ease of breathing the mask while at rest? _____
10. How would you rate the ease of breathing the mask at moderate work level? _____
11. How would you rate the ease of breathing the mask at heavy work levels? _____
12. How would you rate the ability of the mask to remain unfogged? _____
13. How would you rate the accessibility and operation of the nose-clearing device? _____
14. How would you rate the ease of clearing the mask after it has been flooded? _____
15. How would you rate the ease of speaking while wearing the mask with the u/w communications? _____

16. How would you rate the ease of speaking while wearing the mask? _____
17. How would you rate the understandability of other divers while wearing the mask using u/w communications? _____
18. How would you rate the understandability of other divers wearing the mask, using mouthpiece to mouthpiece method, with the T-bit removed from mouth? _____
19. How would you rate the ease of doffing the mouthpiece? _____
20. How would you rate the ease of donning the mouthpiece? _____
21. How would you rate the ease of clearing the mouthpiece and oral mask? _____
22. How would you rate the seal of the mask with the mouthpiece removed? _____

Please provide any additional information or comments about the mask and EBS assembly. _____
